CHAPTER 7.—MANAGING EXCESS GAS EMISSIONS ASSOCIATED WITH COAL MINE GEOLOGIC FEATURES

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In This Chapter

- ✓ Geologic features associated with anomalous methane emissions
- ✓ Gas outbursts and blowers
- ✓ Methane drainage strategies for mitigating anomalous methane emissions

and

- ✓ General considerations for a methane drainage program

This chapter summarizes how certain geologic features may be associated with unexpected increases in gas emissions during coal mining. These unexpected emissions have the potential to create explosive conditions in the underground workplace. Also discussed are the generally used practices to alleviate potential hazards caused by gas emissions associated with these geologic features.

INTRODUCTION

Unforeseen mine gas emissions in quantities sufficient to create hazardous conditions have been attributed to sources outside the mined coalbed since the first documentation of methane explosions in coal mines [Payman and Statham 1930]. Geologic features such as faults have long been recognized as conduits for gas flow from strata adjacent to mined coalbeds [Moss 1927; Payman and Statham 1930]. Other features such as sandstone paleochannels, clay veins, and localized folding have also been recognized for their impact on gas emissions into mine workings [Darton 1915; Price and Headlee 1943; McCulloch et al. 1975; Ulery and Molinda 1984].

The fact that strata adjacent to mined coalbeds can emit large quantities of methane gas into mine workings is not surprising from a theoretical perspective. Many researchers have recognized that during the burial and diagenesis of the organic matter forming today's minable coalbeds, similar dispersed organic matter in adjacent strata has produced methane in quantities far exceeding the storage capacity of the coal and surrounding rock [Juntgen and Klein 1975]. It is not surprising then that large quantities of methane can remain trapped in these strata. A potential hazard occurs when mining of a nearby coalbed causes pressure differentials and mining-induced fractures conducive to gas flow into the mine workings from these strata. This gas flow may be facilitated or temporarily impeded by the presence of geologic structures or anomalies.

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Anomalous, unanticipated methane emissions are often related to the interception of geologic features, such as paleochannels, faults, and clay veins, by mine workings. Furthermore, these features can also contribute methane emissions before being intercepted by mining.

For the purpose of discussion in this chapter, gas emissions associated with geologic features are divided into two categories. The first includes subtle emission events that are often associated with various geologic features or anomalies. These emissions are often not easily detected without instrumentation, but may lead to hazardous accumulations of methane if not remedied. The second category includes large-scale, easily recognizable emission events such as blowers or outbursts that potentially have immediate and often catastrophic consequences. Documented methods to recognize and remedy both types of hazards have been established worldwide and are discussed here.

This chapter summarizes current technologies for recognizing and remediating gas emission hazards associated with various geologic features. Although emphasis is placed on recognized hazards in U.S. coal mines, hazards not well-documented in these mines, such as gas outbursts, are also discussed due to the potential for such occurrences in the future as mines extract deeper and gassier seams.

INCREASED GAS EMISSIONS ASSOCIATED WITH GEOLOGIC FEATURES

In the United States, gas emission events associated with geologic features constitute a fairly common hazard in coal mining. These events are neither as obvious nor as immediate as outbursts or blowers, which are discussed later. However, they can pose significant risks. These emission events are often difficult to detect without instrumentation and underground surveys.

Detailed mapping of geologic features can assist in predicting potential emission hazards and designing methane drainage systems to prevent them.

This section will consider techniques to detect and remediate anomalous gas emissions associated with geologic features such as sandstone channels/lenses, adjacent source beds, clay veins, joints, fractures, and small-scale faulting. Also included is a discussion of igneous intrusions and their potential impact on gas storage and emissions.

Sandstone channels/lenses. Sandstone paleochannel deposits or other lenticular sandstone deposits adjacent to mined coalbeds historically have been documented as gas reservoirs [Darton 1915; Price and Headlee 1943]. The gas may have been generated in situ from organic matter deposited with the sand, or it may have migrated to the paleochannel from subjacent coalbeds or other organic-rich rock strata. These gas-bearing sandstones generally have a greater permeability than other rock strata in coal mining areas. Once a gas flow pathway is established to the mine workings, via either the relaxing of naturally occurring joints, clay veins, faults, or mining-induced fractures, then gas emissions from these sandstones may be quite pronounced and often produces hazardous conditions.

Methane emissions from sandstone paleochannels is a well-known problem in the Pittsburgh Coalbed in Pennsylvania and West Virginia [McCulloch et al. 1975]. At a mine in northern West Virginia, gas was documented to be migrating from a sandstone channel to mine workings through clay vein-related fractures [Ulery and Molinda 1984]. The sandstone paleochannel deposit above the Pittsburgh Coalbed was a significant gas reservoir that was still flowing 370,000 cfd of gas into a methane drainage system 2 years after it was installed.

Delineating problematic sandstone bodies is best accomplished by an exploratory core drilling program of sufficiently close spacing to accurately delineate the extent and trend of the sand unit [Houseknecht 1982]. Also, evaluating the gas content/flow potential of sandstone units is necessary to determine if emissions will be of sufficient volume to pose a potential hazard. This can be accomplished by laboratory testing of core samples for reservoir properties such as porosity and permeability, well testing, or direct gas measurements underground in the vicinity of the feature [Diamond 1994].

When sandstone bodies, either in floor or roof strata, are encountered that pose a gas emission hazard, remediation may be accomplished by vertical surface methane drainage boreholes (Figure 7–1, borehole A). However, in-mine methane drainage boreholes may be the most economically viable solution. In Figure 7–1, boreholes B, C, and D show vertical, in-mine cross-measure, and horizontal degasification borehole configurations, respectively, for methane drainage of a gas-bearing paleochannel deposit in the roof strata. The same configurations of surface or in-mine boreholes would also be applicable to gas-bearing sandstone deposits in floor strata.

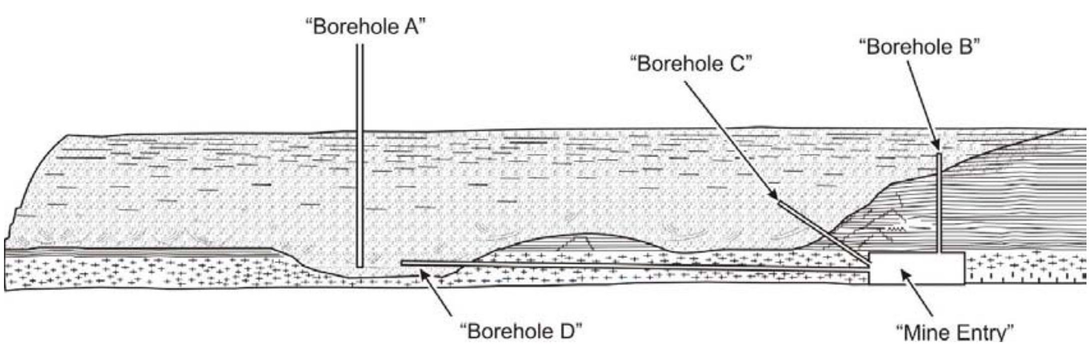

Figure 7–1.—Methane drainage scenarios for paleochannels.

Vertical methane drainage boreholes drilled from the surface usually require both dewatering and hydraulic fracturing for maximum effectiveness. Horizontal, cross-measure, or vertical underground degasification boreholes may also need to remove water to effectively produce gas. These methane drainage systems are fully explained and referenced by Diamond [1994].

Gas-bearing paleochannel deposits or adjacent coalbeds may require surface or cross-measure methane drainage boreholes.

Coalbeds and other adjacent gas source beds. Historical mining experience and research have shown that coalbeds adjacent to the mined seam can contribute significant quantities of methane gas into active workings [Finfinger and Cervik 1979; Ayruni 1984; Diamond et al. 1992]. Degasification of these coalbeds may be accomplished through vertical or directional boreholes drilled from the surface. Occasionally, in-mine vertical, cross-measure, or directional boreholes are used to reduce potentially explosive accumulations of gas [Finfinger and Cervik 1979; Ayruni 1984; Diamond 1994].

In addition to nearby coalbeds, other adjacent strata may also be significant gas reservoirs and contribute unexpected emissions into mine workings. Shales and siltstones rich in organic matter often contain significant quantities of methane gas [Darton 1915; Johnson and Flores 1998]. Although these formations may have a large gas storage capacity, permeability is usually very low. Thus, these rocks may not release gas until mining-induced fractures increase their permeability and provide a pathway for gas migration to the mine workings. In studying the gas content of U.K. coalbeds, Creedy [1988] concluded that although the gas contents and porosities of these rocks are low, a well-developed joint or fracture system could facilitate gas release from these strata. Therefore, it may be assumed that if certain organic-rich rocks adjacent to mined coalbeds have sufficient gas content, migration via joints or fractures into the workings could generate hazardous explosive conditions. Methane drainage methods similar to those discussed previously for adjacent coalbeds are usually appropriate for adjacent noncoal gas-bearing strata as well.

Large- and small-scale structural faulting. For this discussion, large-scale faults are loosely defined as having tectonically activated and structurally mappable features, with lengths greater than 500 m (1,640 ft) and vertical movement of at least 10–20 m (33–66 ft). Small-scale faults are distinguished from large-scale faults by their limited extent both horizontally and vertically. Faults may have a profound effect on gas emissions into mine workings and may also be associated with outbursts and blowers. Usually, the presence of large-scale faulting is known from regional geologic mapping and/or exploration boreholes. In certain cases, these large faults may act as barriers to gas flow, especially if they contain impermeable fault gouge or the displacement causes impermeable rock above or below the mined coalbed to abut against it [Diamond 1982]. In these situations, large volumes of gas can be trapped behind the fault at pressures higher than that of the mine atmosphere. If mine development proceeds through the fault by ramping upward or downward into the displaced, high-pressure coalbed gas reservoir, the potential for sudden, excess gas emissions must be addressed.

Large-scale faults may also act as conduits for gas flow or blowers into the mine workings from gas-enriched strata above or below the mined coalbed. This is especially likely due to stress redistributions as mining approaches a large-scale fault. In Germany, Thielemann et al. [2001] showed that in nonmined regions, normal faults regularly act as gas conduits for surface emissions into the atmosphere from deep (60–870 m (197–2,854 ft)) formations such as coalbeds. Thielemann et al. further demonstrated that distinctly higher surface gas emission rates occurred from normal faults in mined areas, presumably caused by the increased permeability of the fault and associated strata in response to mining. Therefore, it would seem likely that such faults could easily become pathways for gas emissions into mine workings from adjacent source beds. In the United States, Clayton et al. [1993] noted similar findings in the Black Warrior Basin.

Methane drainage from potential gas problem areas associated with large-scale faulting may best be accomplished through surface boreholes if the faulted areas in question are well mapped. In lieu of this, unexpected problems associated with large-scale faulting may be alleviated by underground cross-measure boreholes designed to penetrate the fault zone and/or the gas source bed.

Small-scale faults have limited lateral extent and are often vertically confined to one or two strata layers. In coal mining districts, small-scale faults are often, but not exclusively, related to differential sediment compaction phenomena. Examples of these faults are illustrated by Iannacchione et al. [1981].

Little documentation is available on the effects of small-scale faults on gas emissions. However, based on descriptions by Iannacchione et al. [1981], it would seem reasonable to conclude that these types of faults, if they have any effect at all, could possibly act as more limited barriers to gas migration compared to the previously discussed large-scale faults. Prediction of these small-scale features can be difficult, even with detailed underground mapping. The coalbed near these features often displays abnormal thickening, undulations, or pulverizing, which may indicate that these types of faults are being approached. However, if small-scale faults are encountered and found to adversely influence gas emissions, degasification through short horizontal or cross-measure-type boreholes ahead of the working face is feasible if these faults can be mapped and/or anticipated.

Whether large- or small-scale, displacement faults are generally of two basic types: normal or reverse. Small-scale normal faults are often associated with differential compaction phenomena near sandstone channels. Large-scale normal faulting is often associated with regional uplifts and/or deep plutonic activity. Reverse faults, on the other hand, are often associated with mountain-building tectonics and regional compressional forces. Low-angle reverse faults are termed “thrust faults” and are often very large-scale regional features. Because normal faults are usually associated with tensional forces and reverse faults with compressional forces, they would seem most likely to act as gas conduits and barriers, respectively. However, there is no conclusive documentation to that effect.

Geologic mapping of faults is needed to determine the most efficient gas drainage system.

Figure 7–2 shows a mine entry approaching a normal fault on the “footwall” side. The remaining coal reserve ahead of (and below, due to the fault) the approaching entry often poses an emission hazard, i.e., although the normal fault may potentially be a gas conduit, until mining redistributes stresses, it is not generally an open conduit for gas flow as is the normal coal cleat system. Therefore, when the entry is ramped downward to mine the remaining reserve, hazardous conditions may occur when the gas trapped behind the fault is suddenly released into the mine entry. Optimum degasification of such potential hazards is best accomplished via vertical methane drainage boreholes drilled from the surface (Figure 7–2, borehole B). Alternatively, directional methane drainage boreholes from the mine entry (Figure 7–2, borehole A) could be used.

If a normal fault is encountered from the lower “hanging” wall side (Figure 7–3), vertical methane drainage boreholes drilled from the surface (Figure 7–3, borehole A) are probably the only viable method to remediate the hazard due to the geometry of this condition.

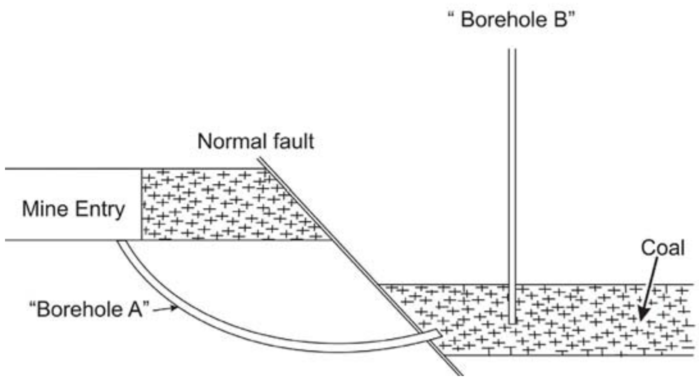

Figure 7–2.—Methane drainage of a normal fault from the “footwall” side.

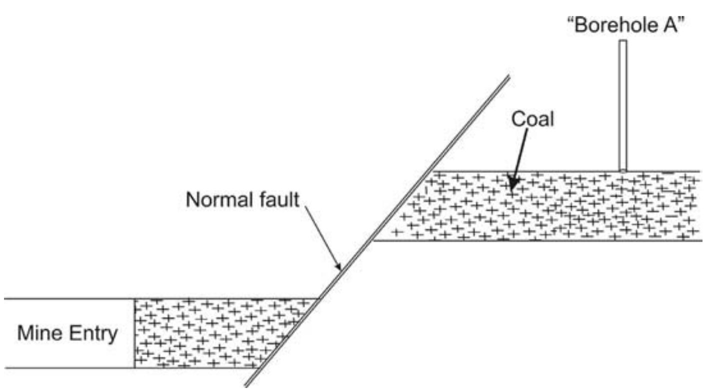

Figure 7–3.—Methane drainage of a normal fault from the “hanging” wall side.

Reverse faults tend to form by compressional forces and therefore may often act as barriers to flow, causing gas buildup behind them. Figure 7–4 shows a mine entry approaching a reverse fault on the “hanging” wall side. In most cases, but especially if the faulting is large-scale, vertical methane drainage boreholes drilled from the surface (Figure 7–4, borehole C) are probably the most viable option to alleviate potential emission hazards. Other options include vertical in-mine boreholes (Figure 7–4, borehole A) or directional in-mine boreholes (Figure 7–4, borehole B). Reverse faults, where mining approaches from the “footwall” side, are optimally addressed with in-mine cross-measure-type boreholes (Figure 7–5, borehole A) or vertical methane drainage boreholes drilled from the surface (Figure 7–5, borehole B).

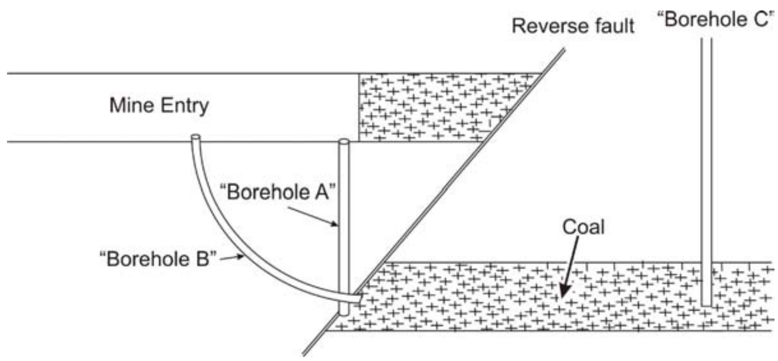

Figure 7–4.—Methane drainage of a reverse fault from the "hanging" wall side.

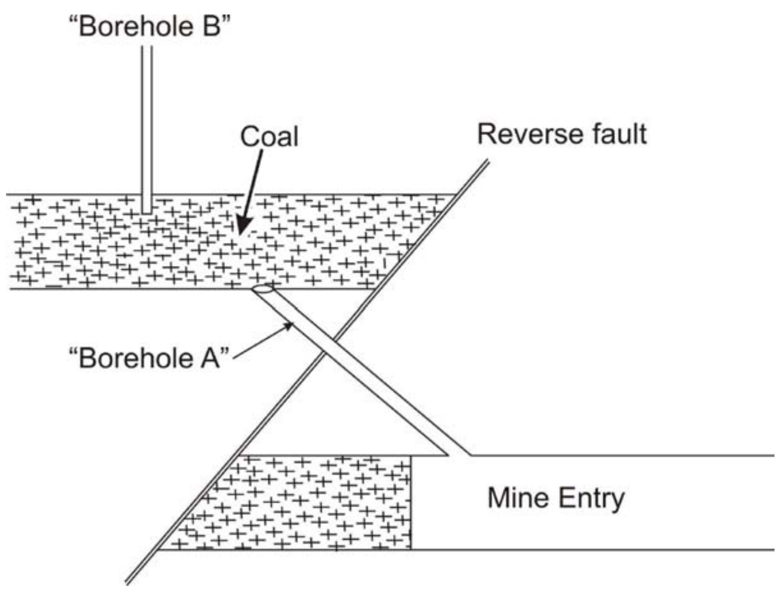

Figure 7–5.—Methane drainage of a reverse fault from the "footwall" side.

Joints, cleats, and fractures. Joints, cleats, and fractures are ubiquitous features in most coal measure rocks and are related to the confining stress fields acting upon those strata during burial, diagenesis, and uplift. Generally, these features follow a systematic pattern. Joints are closely spaced with even walls, whereas fractures are more widely spaced with irregular walls [Nickelsen and Hough 1967]. Joints usually occur in orthogonal pairs (at an approximately 90° orientation to each other), and in coalbeds, these joint sets are referred to as "cleats."

The main joints and cleats of any given set are generally more continuous and are the dominant migration pathways for gas [McCulloch et al. 1974]. They are referred to as "systematic joints" and "face cleats," respectively. The corresponding joints and cleats at 90° to the main features are referred to as "nonsystematic joints" and "butt cleats," respectively. These joints and cleats generally terminate against the systematic joints and face cleats, making them notably less continuous. When coalbeds are mined, the redistribution of stresses allows cleats to expand and facilitates gas migration through the coal to the face. Similarly, the stress redistribution opens joints and fractures in roof and floor strata, facilitating gas migration from adjacent strata.

The ubiquitous nature of joints and the unpredictable spacing of fractures make prediction and remediation of abnormal gas emissions related to these features difficult. It is important for operators to realize that although joints and fractures may contain free gas at the face, their real hazard potential is as a conduit for unexpected gas flows to the mine workings from within the coalbed and/or other source beds adjacent to the mined coalbed. These types of conditions are most often recognized when the continuous miner or longwall shearer is deenergized due to the machine-mounted methane sensors reading concentrations above the allowable limits. The most obvious solution to this problem would be to increase the face ventilation, if not already at the practical limit.

If past experience indicates that excess emissions may be encountered in a developing section, the mine operator should consider an underground horizontal borehole methane drainage system or vertical methane drainage boreholes drilled from the surface to remove gas prior to mining. Mine operators should always be aware of regional joint and fracture trends to facilitate prediction and remediation of abnormal emissions associated with joints and fractures.

Clay veins. Clay veins or clastic dikes (Figure 7–6) are sedimentary intrusions, usually from overlying strata, that invade the coal in a vertical or near-vertical orientation. Their appearance in cross-section is not unlike an igneous dike, hence their name. Clay veins tend to be systematic in occurrence and are often related to differential compaction/diagenetic processes, but can also be influenced by tectonic processes.

These features, their characteristics, and modes of formation have been widely documented in U.S. coal mines [Chase and Ulery 1987]. Clay veins, which are generally composed of very fine-grain sediment or clay, are virtually impermeable barriers to gas migration in coalbeds. Therefore, they tend to have a "damming" effect on gas flow when approached in a developing section. When a continuous miner or longwall shearer penetrates a clay vein with gas trapped behind it, the abnormally high emissions may cause production interruptions due to methane concentrations above the legal limit, and in a worst-case scenario, an explosive methane/air mixture could ignite.

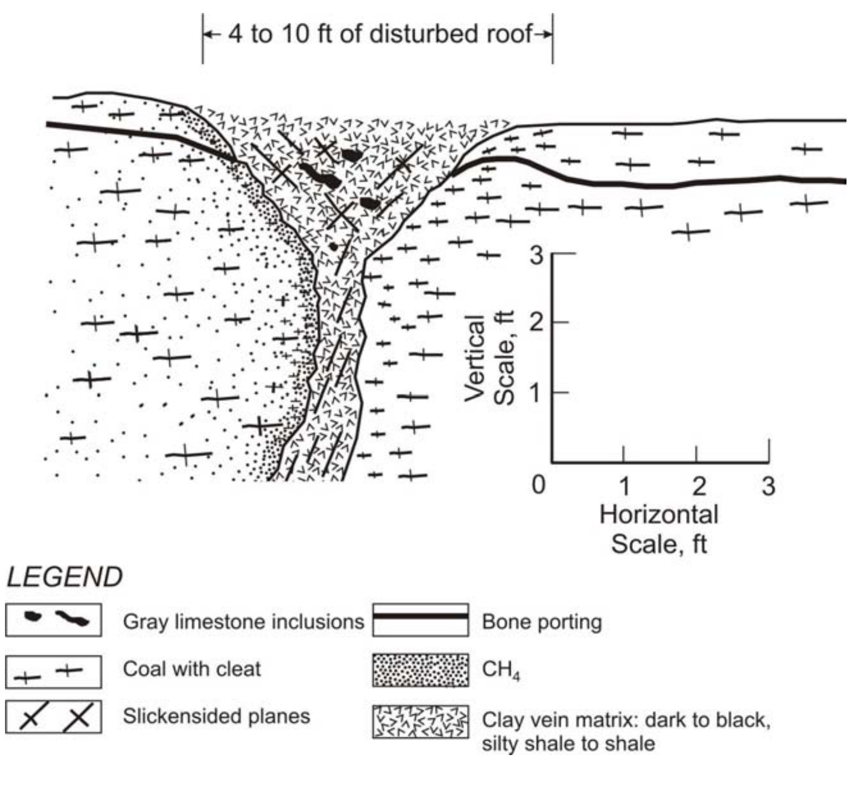

Figure 7–6.—Typical clay vein acting as a barrier to gas migration.

Clay veins have a well-documented history of causing unexpected high gas emissions in the Pittsburgh Coalbed during mining [McCulloch et al. 1975]. Prosser et al. [1981] measured increases in gas flow from 47,000 to 80,000 cfd when a horizontal in-mine methane drainage borehole penetrated a clay vein approximately 800 ft from the face. For a different horizontal borehole in the same study, the gas flow increased from 144,000 to 214,000 cfd when a clay vein was penetrated approximately 2,175 ft from the face. High gas flow rates (>80,000 cfd) from low-angle cross-measure boreholes penetrating clay veins near a gas-bearing sandstone above the Pittsburgh Coalbed have been documented in northern West Virginia [Ulery and Molinda 1984].

In-mine horizontal boreholes can effectively drain gas trapped behind clay veins in advance of mining.

Only experience at a given mine can indicate to the operator if clay veins have the potential for gas emission problems. If methane emission problems are encountered, then underground mapping of clay veins is needed to predict where they will occur in developing sections. Because clay veins can frequently extend hundreds of feet along a given trend [Chase and Ulery 1987], predicting their occurrence in a developing section will allow the operator to anticipate and/or alleviate the potential gas problem.

If the clay vein network in a specific mine has a history of gas emission problems, then horizontal methane drainage boreholes drilled ahead of the face and penetrating the clay vein are probably the most economical and timely method to remediate the potential problem (Figure 7–7, borehole A). Theoretically, if a clay vein network is well-mapped and a large, isolated “cell” is delineated (Figure 7–8), then the gas could be drained through a surface borehole (Figure 7–7, borehole B). Generally, however, this would be a cost-prohibitive course of action, necessitated only in extreme cases or where drilling costs would be low due to shallow depths.

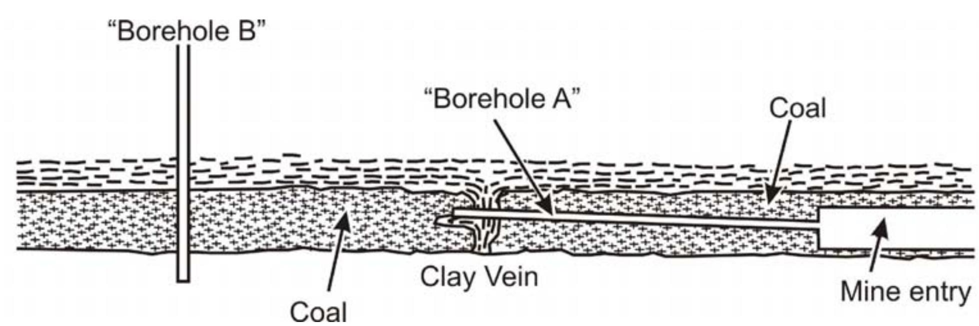

Figure 7–7.—Methane drainage of a clay vein gas barrier.

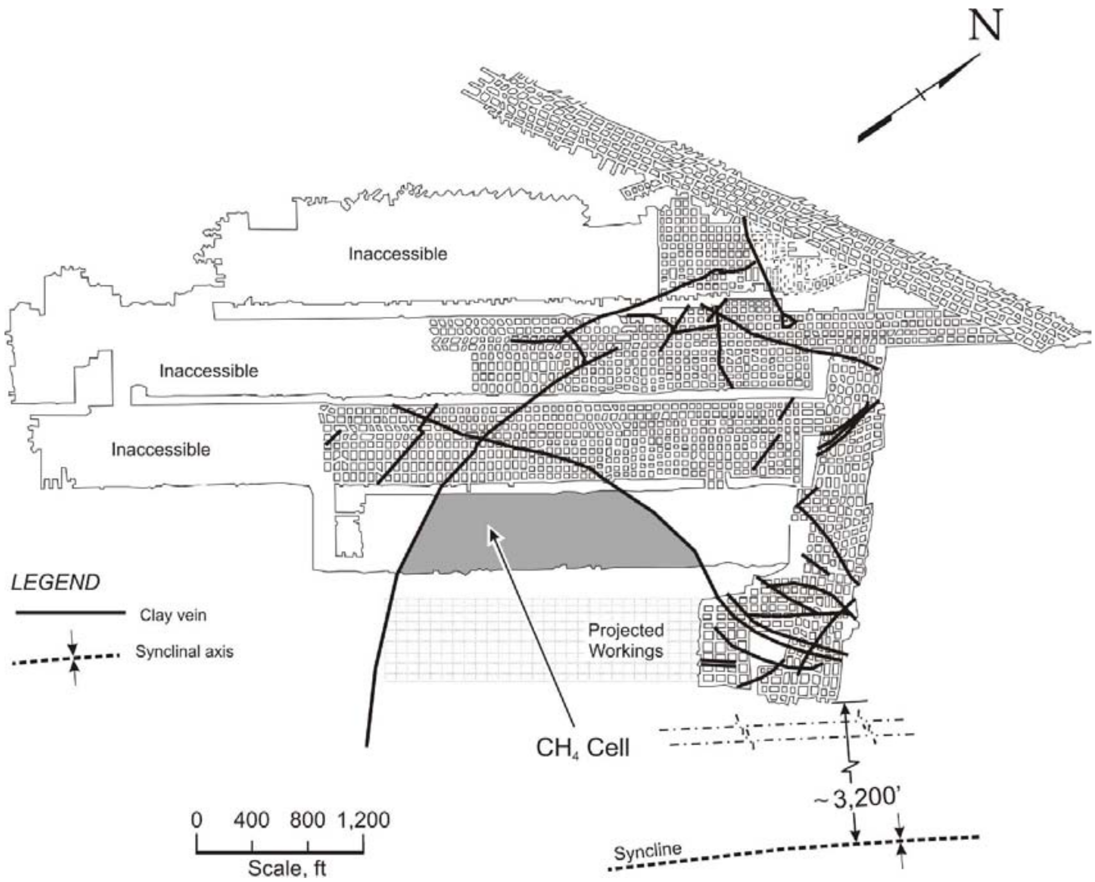

Figure 7–8.—Hypothetical gas cell formed by clay veins (adapted from Chase and Ulery [1987]).

Igneous intrusions. Igneous intrusions into coalbeds and coal measure rocks are not frequent, but not uncommon either. Igneous intrusions into coal measure strata generally will be either discordant features such as dikes, which cut across bedding planes, or concordant features such as sills, which are injected parallel to bedding. Massive discordant features such as plutons are rare in coal measures.

Because igneous intrusions involve magmatic rock injected at elevated temperatures, they cause an alteration and increase in the thermal maturity (rank) of nearby coalbeds and organic matter in rocks [Dutcher et al. 1966]. The degree of coal alteration caused by an igneous intrusion depends on many factors, including the intrusion's temperature, thickness, distance from the coal seam, and cooling rate. Such thermal alteration of organic matter is accompanied by methane gas generation. Therefore, for a given coalbed, localized areas affected by igneous intrusions can be expected to have higher gas contents than normal [Gurba and Weber 2001]. Larger igneous intrusions such as sills may also be responsible for potentially high carbon dioxide concentrations in some coal basins [Clayton 1998].

Discordant igneous dikes, which cut across the coalbed, may not only be expected to increase the in situ gas content due to thermal alteration, they can also act as a barrier or "dam" to gas migration and present hazards similar to clastic dikes when mined through. Predicting the location and orientation of igneous dikes in developing sections is best accomplished by detailed underground mapping in adjacent developed sections. Remediating potential gas emission hazards associated with igneous dikes, as with clastic dikes, is best accomplished by horizontal boreholes drilled from the face to penetrate the dike.

Concordant igneous features such as sills usually cover a far greater area than dikes and can elevate the thermal maturity and gas content of a coalbed over a similarly large area [Gurba and Weber 2001]. However, the greater extent of these features is more conducive to prediction and mapping through conventional exploratory core drilling programs. If associated gas contents and emissions are expected to present a potential hazard, premining methane drainage through vertical methane drainage boreholes drilled from the surface is the optimal method to alleviate the hazard.

GAS OUTBURSTS AND BLOWERS

Although not generally considered to be hazards in domestic mines at present, both outbursts and blowers historically have occurred in certain U.S. mining districts [Darton 1915; Campoli et al. 1985]. The two features are mainly distinguished by their duration of occurrence. Outbursts are sudden, often violent expulsions of large quantities of gas, usually methane, and are generally associated with the ejection of great quantities of coal or other rock material. Blowers, on the other hand, historically have been viewed as the release of large quantities of gas, but over an extended time period of months or even years. Also, blowers are not associated with the expulsion of coal or rock material. A subset of blowers is methane bleeders, which also continually emit gas, but at lower rates and generally for shorter timeframes.

Although not typically associated with U.S. coal mines, gas outbursts occur regularly in certain mining districts worldwide. Typically, the mines in these districts are in a coalbed with high in-place gas contents, coupled with steeply dipping and/or very deep workings. As shallower, more easily extracted coal reserves are depleted in the United States and as mining progresses to deeper, more structurally complex and gassier coalbeds, the potential for gas outbursts will likely increase. Campoli et al. [1985] delineate more than a dozen U.S. coalbeds with outburst potential based on internationally recognized criteria. In fact, gas outbursts have been documented throughout history in U.S. mines with similar conditions.

Historical examples of U.S. outbursts are mentioned by Darton [1915] as occurring in Pennsylvania. Two of these occurred in anthracite mines in steeply dipping coalbeds. Another took place in western Pennsylvania near Connellsville, where Darton noted that 100,000 ft^3 of fresh air per minute for 3 days was required to reduce the methane concentration in the mine air to safe levels. Little additional documentation is presented, and it is not known if rock material was also ejected with the gas. Darton also summarized extensive European documentation of gas outbursts and concluded that these phenomena were usually related to crushed coal zones associated with folds, buckles, and faults.

Lama and Bodziony [1998] compiled a comprehensive overview of outbursts worldwide and their causative factors and prevention. They conclude that the following factors contribute to outbursts: (1) gas content, (2) gas pressure, (3) permeability, (4) sorption/desorption characteristics, (5) stress conditions, (6) coal strength, and (7) geologic factors (often related to tectonic activity). Other modern research on these phenomena has demonstrated two major indicators of outburst potential in coal mines. The first indicator is the coal lithotype. Beamish and Crosdale [1998] demonstrated that coals with high vitrain and/or inertodetrinite lithotypes were more likely to retain the large quantities of gas needed to produce outbursts. A second indicator, documented by Cao et al. [2001], is the association of outbursts with tectonically altered, faulted coals. Cao et al. noted that outbursts in China seem to be associated with tectonic activity that has produced regional thrust and reverse faulting. Such faulting often manifests itself in coalbeds because of their brittle nature compared to the surrounding strata. The coal adjacent to such faults is often severely crushed and pulverized, resulting in significant local changes in the gas storage and migration characteristics of the coal.

Blowers, like outbursts, are not normally associated with coal mining in the United States, but historically they have been noted in the United States and in other mining districts abroad. Darton [1915] summarized documented blower occurrences worldwide and noted the occurrence of blowerlike features in the Pennsylvania anthracite district.

Detection and remediation of outbursts and blowers. Based on past observations, outbursts and blowers are often associated with tectonically disturbed and faulted strata where gassy coals are mined at considerable depth. Thus, mine planners who are aware of such conditions should give some thought to the possibility that they will be extracting coal under conditions that have produced outbursts and blowers in other mining districts.

If large-scale faulting is known and adequately mapped in future development areas, a detailed core-drilling program, coupled with gas content testing of core samples and in situ gas pressure measurements, can detect potential outburst-prone areas. Beamish and Crosdale [1998] recommend, as do Lama and Bodziony [1998], the use of any one of several published gas emission indices as an indicator of proneness to outbursting.

Since outbursts often occur in “nests” or clusters, when such conditions are encountered or anticipated, remediation may be achieved by using gas drainage techniques such as vertical methane drainage boreholes drilled from the surface, horizontal boreholes drilled underground ahead of the face, or (if outburst-prone strata are in the roof rock) cross-measure boreholes [Diamond 1994]. Typically, these boreholes will penetrate the fault system that has altered the coal structure and allowed large quantities of gas to accumulate at great pressure behind it. The boreholes are used to drain gas from the outburst-prone area and to relieve the gas overpressure that drives outbursts. Lama and Bodziony [1998] stress that vertical surface boreholes may be preferred over holes drilled in the coalbed because of the difficulty of maintaining borehole integrity during horizontal drilling in the outburst-prone strata. The difficulty of maintaining borehole integrity is due to the crushed nature of the coal in these areas. Beamish and Crosdale [1998] also recommend water infusion to reduce outburst hazards.

Outbursts are often driven not only by gas pressure, but also by inherent, concentrated stress fields in the rock mass. Hyman [1987] summarizes several methods to reduce in situ strata gas pressures to prevent outbursts. These techniques include the use of modified mine opening geometries, shot firing, and water infusion, all of which have been successfully used abroad to abate outbursts.

Blowers most often emanate from underlying strata. The recommended remediation technique is the use of cross-measure holes angled downward from the mine heading to intercept the fissure or fault, which acts as a gas conduit. The borehole(s) may then be used to drain gas away from the blower outlet in the mine workings.

GENERAL REMEDIATION CONSIDERATIONS

When unanticipated gas emissions cause repeated production interruptions, mine operators must understand that they have a gas problem.

In order to determine the most appropriate course of action to remediate a gas emission problem, the mine operator must make a thorough evaluation of the cause, extent, and severity of the problem. The cause of the problem may be as simple as underestimating the original gas content of the coalbed, or it may be more complex and involve gas sources outside the mined coalbed. Determining the extent of the problem may only entail additional gas content testing [Diamond and Schatzel 1998] of the mined coalbed through exploratory boreholes, or it may require extensive underground methane monitoring surveys or gas monitoring instrumentation. Also, detailed underground mapping of geologic features may be needed to delineate and predict gas emission trends. Remediation may require only an increase in ventilation airflow to the face, or it may require an extensive mapping and drilling program to delineate and alleviate the problem.

Often when unusually high methane emissions are unexpectedly encountered during mining, operators must make quick decisions about how to address the problem. A prudent operator should weigh several pertinent factors before embarking on any course of action.

If increased ventilation capacity alone cannot alleviate the problem, operators, especially smaller ones, do not always have the available expertise, human resources, or equipment to evaluate the problem and implement either a surface or in-mine borehole methane drainage program and will need to rely on outside consultants. Methane drainage systems drilled from the surface generally require fewer boreholes, but need good geologic control to effectively hit the gas-bearing zone. These boreholes generally require dewatering, hydraulic fracturing, and sufficient time to be optimally effective. Methane drainage systems drilled from the surface have associated issues with the procurement of appropriate and accessible drilling sites and environmental concerns for water disposal and site reclamation.

In-mine methane drainage systems generally require more boreholes and may also require dewatering. However, they can be drilled relatively quickly and require less time to be optimally effective. Additionally, in-mine methane drainage systems will require an underground gas-gathering system to transport gas from the boreholes to the surface, usually via one or more vertical boreholes drilled for that purpose. In-mine systems may also have accessibility constraints due to poor roof or floor conditions or other mining-related safety issues in the area where holes need to be drilled.

It should be noted that there may be regulatory requirements that need to be addressed when methane drainage systems are associated with mining operations. In the United States, a recent bulletin issued by the Mine Safety and Health Administration (MSHA) states that “MSHA has determined that [coalbed methane] wells are subject to the ventilation plan and mapping requirements that apply to methane degas holes” [McKinney 2005]. If coalbed gas of sufficient quality and quantity is produced by the methane drainage system, the gas has the potential to be sold for commercial use, which helps defray the costs of methane drainage.

After a methane drainage system is put into place, it can only be effective as long as it is operating properly. Operators must consider who will operate and maintain the system once it is installed. If installed in-house, personnel may need to be permanently assigned to the project. If outside contractors are used for the installation, will they be retained for long-term operation and maintenance, or will mine personnel need training to operate and maintain the system once the contractor leaves?

The economics of any methane drainage system under consideration involves weighing the pros and cons of all of the factors discussed above. The final remediation plan will hopefully be one that, under the site-specific circumstances, will create a safer underground workplace for the miners while minimizing capital investment and human resources.

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